


# VERIFICATION OF TRANSLATION

I, Wakako Anzai, of c/o SAKAI International Patent Office, 2-6, Kasumigaseki 3-chome, Chiyoda-ku, Tokyo 100-0013 Japan, hereby declare that I am a translator of the document attached, and attached document is a true and correct translation made by me to the best of my knowledge and belief.

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Signature of Translator:   
Wakako Anzai

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[Type of Document] Specification

[Title of the Invention] Dispersion compensating module

[Scope of Claims for Patent]

(1) A dispersion-compensating module that compensates for a dispersion and a dispersion slope in a signal wavelength band of a transmission optical fiber, wherein (A) the dispersion-compensating module comprises two or more fibers, (B) when a dispersion value of a total module is  $D$ , the dispersion-compensating module fulfills a condition of  $D \leq -20$  ps/nm/km at a center wavelength in the signal wavelength band, and (C) when a dispersion slope of a total module is  $S$  at the center wavelength in the signal wavelength band, the dispersion-compensating module fulfills a condition that  $D/S$  is within a range from 0.9 times to 1.1 times  $D/S$  of the transmission optical fiber.

(2) The dispersion-compensating module according to claim 1, wherein at least one fiber has a negative dispersion and a negative dispersion slope.

(3) The dispersion-compensating module according to claim 1, wherein each of at least two fibers has a negative dispersion and a negative dispersion slope, and the  $D/S$  has the following relationships:

$(D/S)_{\text{line}} \times 0.8 \leq (D/S)_{\text{dispersion-compensating fiber 1}} < (D/S)_{\text{line}}$

$(D/S)_{\text{line}} < (D/S)_{\text{dispersion-compensating fiber 2}} < (D/S)_{\text{line}} \times$

1.2.

(4) The dispersion-compensating module according to any one of claims 1 to 3, wherein an absolute value of a cumulative dispersion after the transmission optical fiber and the dispersion-compensating module are jointed together is equal to or less than 0.5 ps/nm/km, and an absolute value of a cumulative dispersion slope after the transmission optical fiber and the dispersion-compensating module are jointed together is equal to or less than 0.01 ps/nm<sup>2</sup>/km.

10 (5) The dispersion-compensating module according to claim 1, wherein the signal wavelength band is an optional one band selected from a C-band (1530 to 1565 nanometers), an L-band (1565 to 1625 nanometers), or an S-band (1460 to 1530 nanometers).

15 (6) A dispersion-compensating module that compensates for a dispersion and a dispersion slope in a signal wavelength band of a transmission optical fiber, wherein (A) the dispersion-compensating module comprises two or more fibers, and (B) when a dispersion value of a total module is D, the dispersion-compensating module fulfills a condition of  $D \leq -20$  ps/nm/km at a center wavelength in the signal wavelength band.

(7) The dispersion-compensating module according to claim 6, wherein  
25 each of at least two fibers has a negative dispersion and a

negative dispersion slope, and the D/S has the following relationships:

$$(D/S)_{\text{line}} \times 0.8 \leq (D/S)_{\text{dispersion-compensating fiber 1}} < (D/S)_{\text{line}}$$

line

$$(D/S)_{\text{line}} < (D/S)_{\text{dispersion-compensating fiber 2}} < (D/S)_{\text{line}} \times$$

5 1.2.

(8) The dispersion-compensating module according to claim 6,  
wherein

the two fibers according to claim 7 are fusion-spliced.

10

(9) The dispersion-compensating module according to claim 8,  
wherein

protection means are provided in a fusion-spliced portion.

15 (10) The dispersion-compensating module according to claim 9,  
wherein

the protection means are an ultraviolet-cured resin.

(11) The dispersion-compensating module according to any one of  
20 claims 6 to 9, wherein

the signal wavelength band is an optional one band selected  
from among a C-band (1530 to 1565 nanometers), an L-band (1565 to  
1625 nanometers), or an S-band (1460 to 1530 nanometers).

25 (12) A dispersion-compensating module that compensates for a

dispersion and a dispersion slope in a signal wavelength band of a transmission optical fiber, wherein (A) the dispersion-compensating module comprises two or more fibers, and (B) when a dispersion value of a total module is D, the dispersion-compensating module fulfills a  
5 condition of  $D \leq -20$  ps/nm/km at a center wavelength in the signal wavelength band.

(13) The dispersion-compensating module according to claim 12, wherein  
10 each of at least two fibers has a negative dispersion and a negative dispersion slope, and the D/S has the following relationships:  
 $(D/S)_{\text{line}} \times 0.8 \leq (D/S)_{\text{dispersion-compensating fiber 1}} < (D/S)_{\text{line}}$   
 $(D/S)_{\text{line}} < (D/S)_{\text{dispersion-compensating fiber 2}} < (D/S)_{\text{line}} \times$   
15 1.2.

(14) The dispersion-compensating module according to claim 13, wherein  
the two fibers according to claim 13 are wound around one  
20 bobbin, a fiber having a smaller bending loss than the other fiber in a maximum wavelength in the signal wavelength band is previously wound around the bobbin, and the fiber having a larger bending loss is wound thereafter.

25 (15) The dispersion-compensating module according to any one of

claims 12 and 13, wherein

the signal wavelength band is an optional one band selected from among a C-band (1530 to 1565 nanometers), an L-band (1565 to 1625 nanometers), or an S-band (1460 to 1530 nanometers).

5

(15) A dispersion-compensating module that compensates for a dispersion and a dispersion slope in a signal wavelength band of a transmission optical fiber, wherein (A) the dispersion-compensating module comprises two or more fibers, and (B) when a dispersion value  
10 of a total module is  $D$ , the dispersion-compensating module fulfills a condition of  $D \leq -20$  ps/nm/km at a center wavelength in the signal wavelength band.

(16) The dispersion-compensating module according to claim 15,  
15 comprising pumping means, and the dispersion-compensating module is used as a Raman amplification medium.

(17) The dispersion-compensating module according to claim 15,  
wherein  
20 the signal wavelength band is an optional one band selected from among a C-band (1530 to 1565 nanometers), an L-band (1565 to 1625 nanometers), or an S-band (1460 to 1530 nanometers).

[Industrial Applicability]

The present invention relates to an optical fiber for wavelength  
25 division multiplexing transmission, and a wavelength division

multiplexing transmission line constituted by the optical fiber.

[Prior Art]

A dispersion-compensating module using a dispersion-compensating fiber that compensates for a dispersion and a dispersion slope in a transmission line is used. Conventionally,  
5 separate dispersion-compensating modules are used to compensate for the C-band and the L-band as it is difficult to compensate for these bands at the same time.

[Problems to be Solved by the Invention]

10 However, as the transmission speed is increasing, dispersion tolerance becomes severer. Therefore, the dispersion compensation becomes insufficient within the C-band or the L-band in which one dispersion-compensating fiber is used to compensate for the dispersion and the dispersion slope in the transmission line.

15 [Means to Solve the Problems]

Two or more fibers constitute a dispersion-compensating module, thereby to more increase the dispersion compensation capacity of the module as a whole.

[Embodiments]

20

|                                 | Dispersion<br>at 1550<br>nanometers | Dispersion<br>Slope at<br>1550<br>nanometers | D/S   | Length |
|---------------------------------|-------------------------------------|--|-------|--------|
|                                 | ps/nm/km                            | Ps/nm/km                                     |       | km     |
| Transmission line               | 5.0                                 | 0.045  | 111.1 | 80.0   |
| Dispersion-compensating fiber 1 | -95.0                               | -1.00  | 95    | 3.6    |
| Dispersion-compensating fiber 2 | -120                                | -0.90  | 133.3 | 0.6    |
| After compensation              | -0.175                              | -0.0068                                      | -     | -      |

A dispersion-compensating module can be manufactured by winding two dispersion-compensating fibers shown in the table around separate bobbins respectively. The two dispersion-compensating fibers are integrated into one module by (A) directly fusion-splicing between the fibers, (B) fusion-splicing between the fibers via a single mode fiber (hereinafter, "SMF") or a dispersion shifted fiber (hereinafter, "DSF") as an intermediate fiber, or (C) connecting between the fibers via a connector. In the case of the method (A), though a splice loss can be decreased, an adjustment of a splicing condition for each combination of kinds of dispersion compensating fibers is required. In the case of the method (B), to determine a fusion-splicing condition for splicing the SMF or the DSF with the dispersion-compensating fibers is only required, and the adjustment of the splicing condition can be simplified. However, the method (B) tends to generate a larger loss than the method (A) because of an increase of fusion-spliced point. In the case of the method (C), the connection is easy, and makes it



possible to replace the dispersion-compensating fiber. Therefore, the method (C) is suitable for controlling a total dispersion value, but generates a larger connection loss because of the presence of the connector. Anyhow, any one of these methods can be optionally  
5 selected to match the usage.

In the case of the fusion-splice, it is required to remove a fiber coating for using the splicing. Therefore, a fusion-spliced portion needs to be protected after the splice. As the protection means, (A) a method for covering by a sleeve or (B) a method for coating and curing  
10 an ultraviolet cured resin is used. Particularly, in the case of splicing the fibers according to the method (B), when a diameter of the fiber coating and a diameter of the fusion-spliced portion are matched, the two fibers can be wound around one coil.

The dispersion-compensating fiber 1 having a smaller D/S than  
15 the dispersion-compensating fiber 2 has a larger bending loss than the dispersion-compensating fiber 2 at a maximum wavelength (1565 nanometers) of the C-band. Therefore, in order to avoid an increase in the winding loss, the fiber 2 is previously wound around the coil, and the fiber 1 is wound later.

20 When the D/S of the dispersion-compensating fiber becomes smaller, the bending loss tends to be larger. When the D/S becomes larger, the bending loss becomes smaller, but dispersion-compensating rate is smaller at the same time. Therefore, it becomes necessary to make smaller the D/S of the dispersion-compensating fibers to be  
25 combined together, as the result, the bending loss becomes large.

Therefore, a range of 0.8 to 1.2 times the D/S of the transmission line is selected for the D/S of the dispersion compensating fibers.

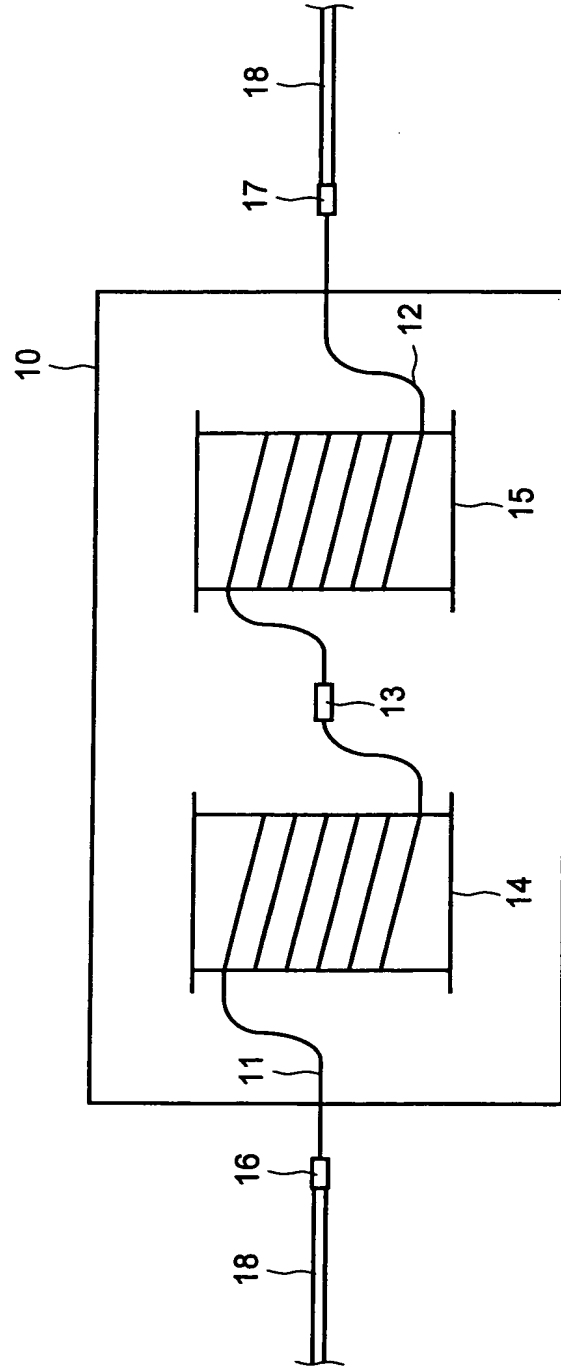
A dispersion-compensating module having the fibers 1 and 2  
5 jointed together in the length shown in the table is prepared, and this dispersion-compensating module is used to compensate for the dispersion of a conventional SMF having a length of 80 kilometers. As a result, the cumulative dispersion and the cumulative dispersion slope in 1550 nanometers can be suppressed to the value shown in the table  
10 after compensation.

In the above-mentioned embodiment, the SMF is used for the transmission line. However, non-zero dispersion shifted fiber (NZ-DSF) can also be used in a similar manner when dispersion-compensating fibers are suitably selected. While the  
15 C-band with 1550 nanometers as a center is used for the signal wavelength band, the L-band and the S-band can also be used in a similar manner when dispersion-compensating fibers are suitably selected.

#### [Effects of the Invention]

20 The present invention provides a dispersion-compensating module that realizes a sufficiently small cumulative dispersion and a sufficiently small cumulative dispersion slope necessary for a high-speed transmission.

FIG.1



# FIG. 2

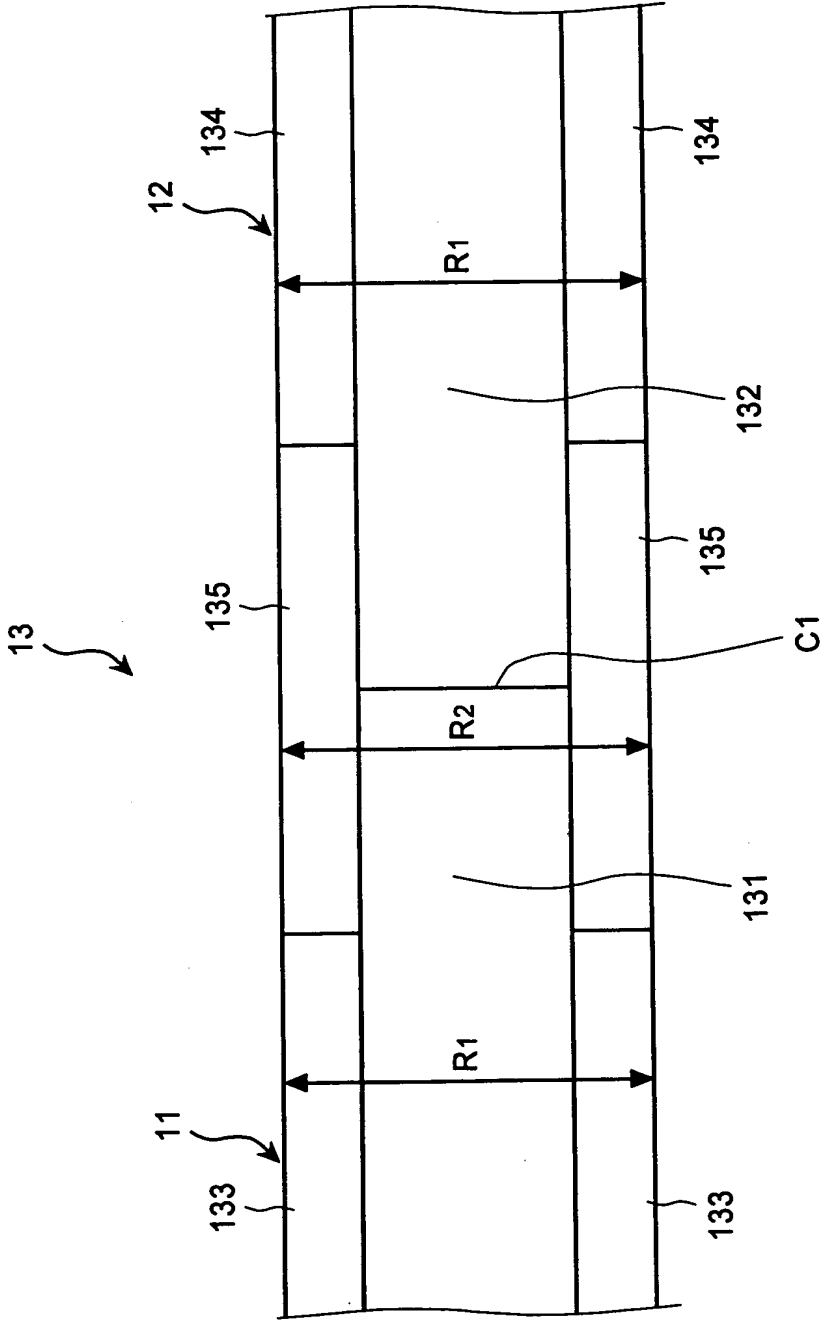


FIG.3

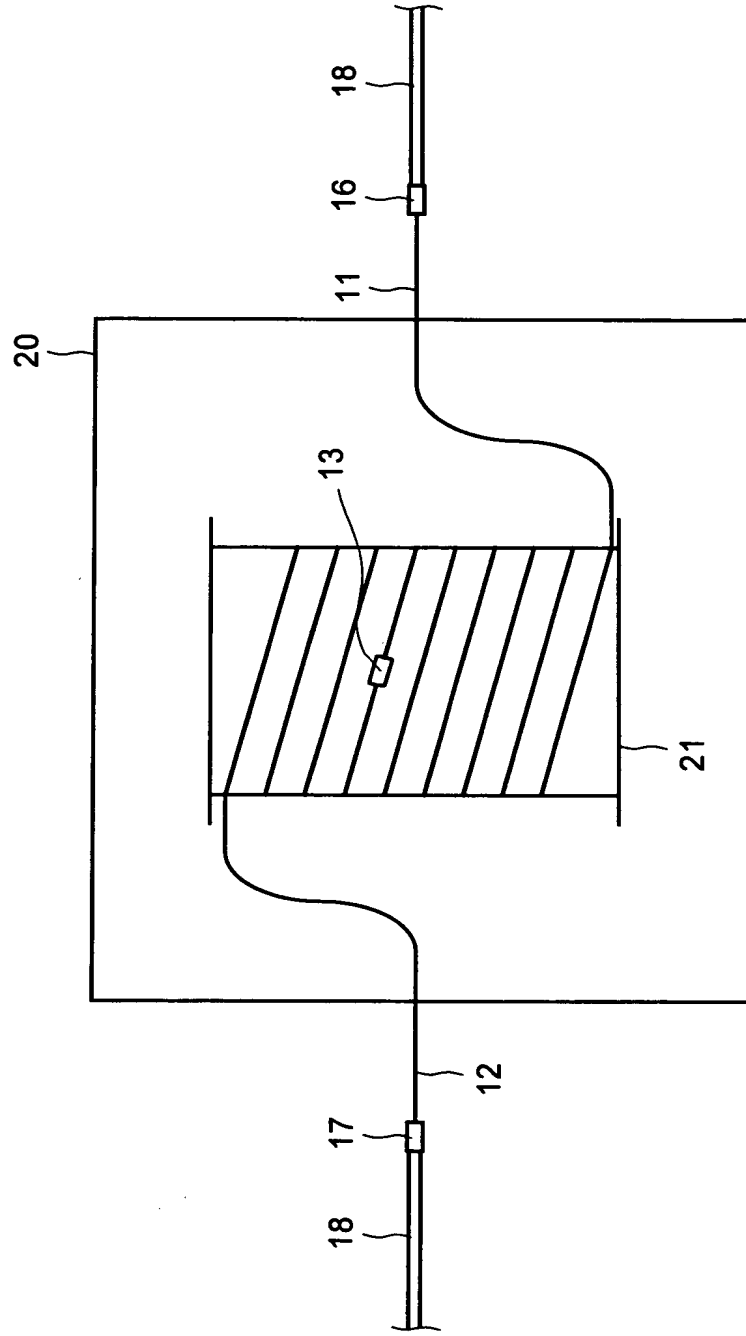


FIG.4

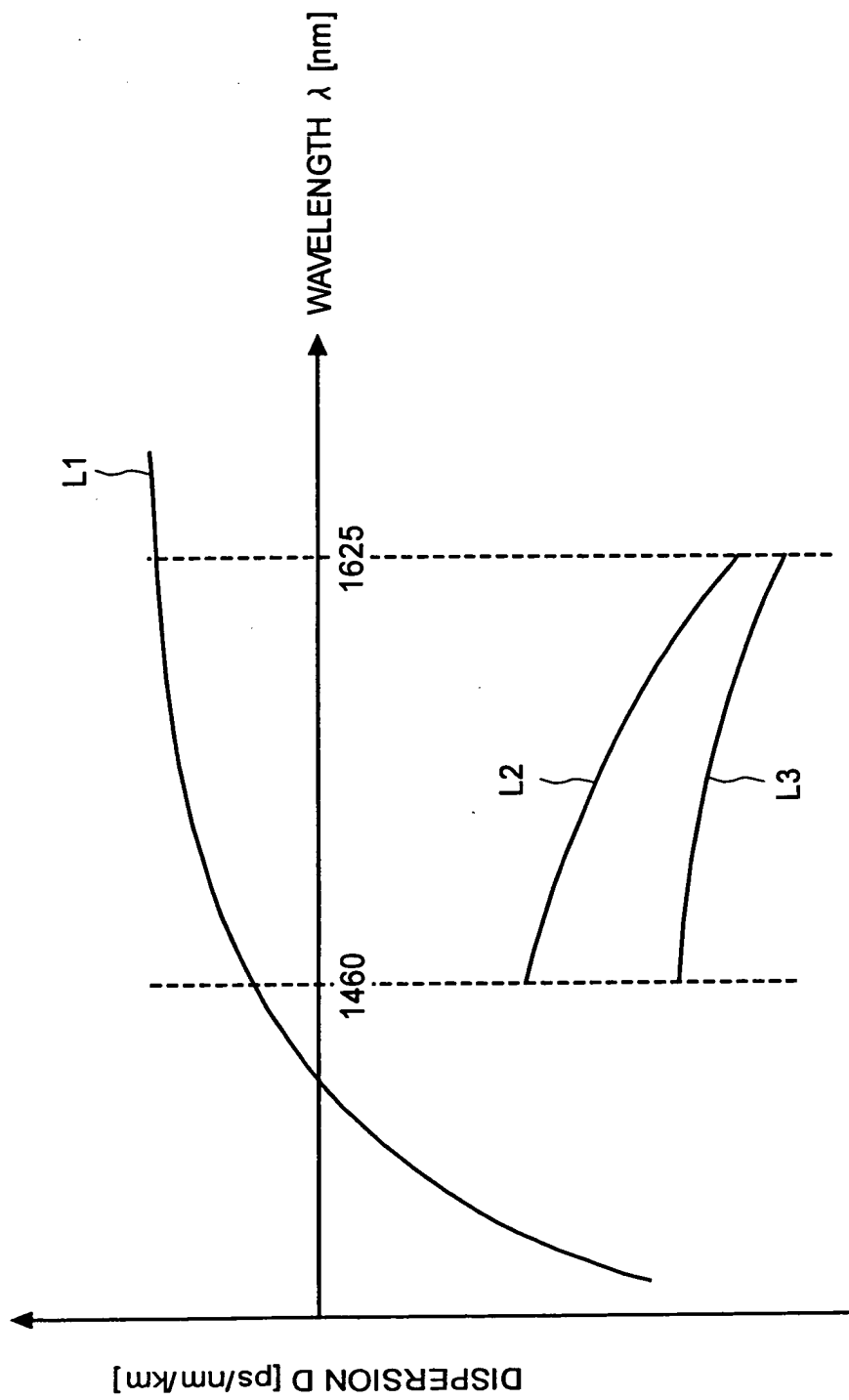


FIG.5

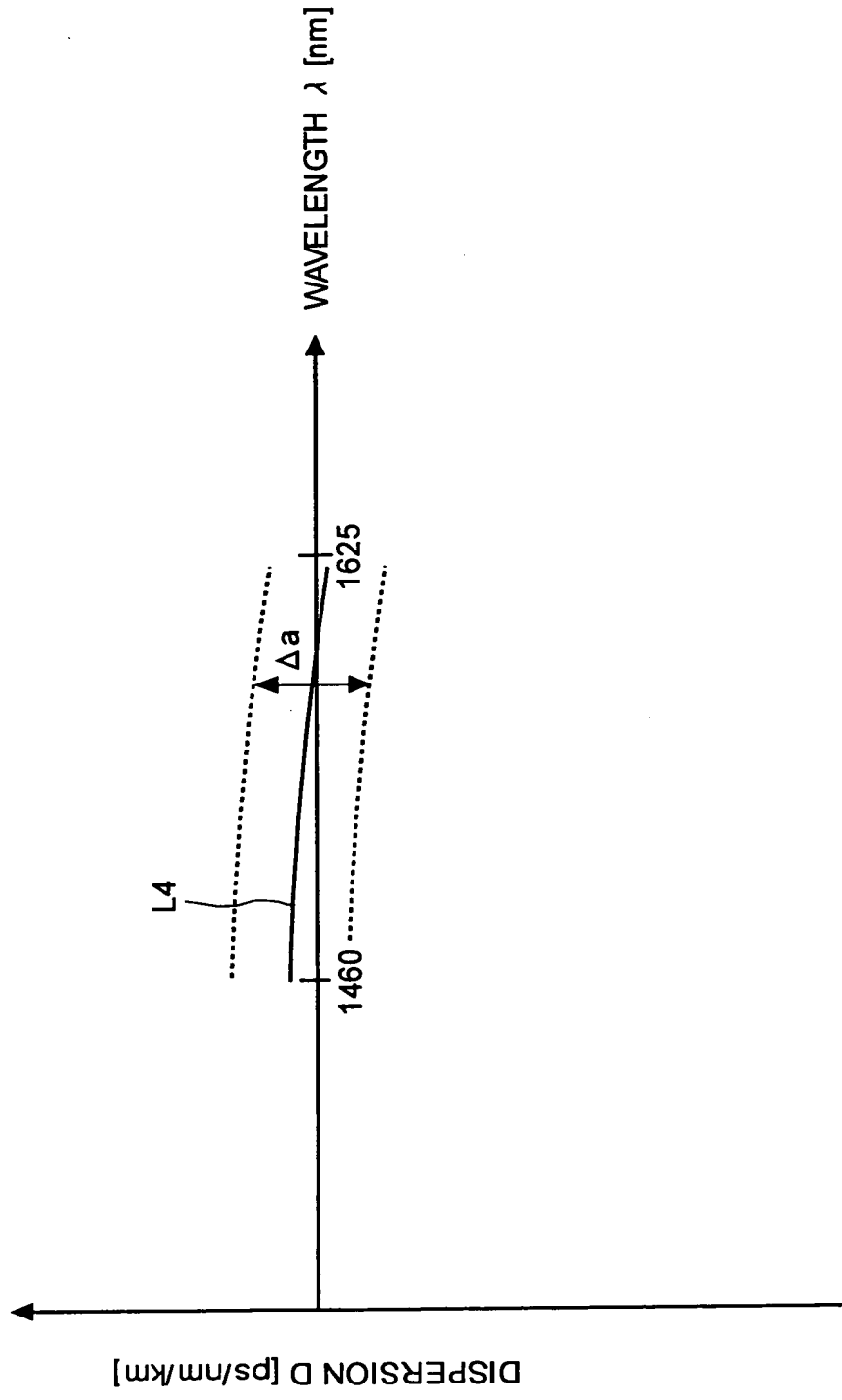


FIG.6

